Mysore J. Agric. Sci., 57 (3) : 146-152 (2023)

Agro-economic Evaluation of Aerobic Rice + Legume Intercropping System under Varying Levels of Nitrogen

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AUTHORS CONTRIBUTION

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Received : March 2023
Accepted : July 2023

ABSTRACT

An experiment was carried out at College of Agriculture, Padannakkad, Kerala Agricultural University (KAU) to analyse the productivity of aerobic rice intercropped with legumes (black gram and cowpea) under varying levels of N (50, 75, 100% RDN). It was laid out in RBD with 9 treatments and 3 replications. Treatments include T_1: Sole crop of black gram, T_2: Sole crop of cowpea, T_3: Sole crop of aerobic rice, T_4: Intercrop of black gram + aerobic rice with RDN, T_5: Intercrop of black gram + aerobic rice with 75% RDN, T_6: Intercrop of black gram + aerobic rice with 50% RDN, T_7: Intercrop of cowpea + aerobic rice with RDN, T_8: Intercrop of cowpea + aerobic rice with 75% RDN, T_9: Intercrop of cowpea + aerobic rice with 50% RDN. The results showed that the number of tillers/ hill (24.4) and productive tillers/ hill (21.27) were significantly highest in black gram + aerobic rice with RDN (T_4). The highest number of spikelets/ panicle (77.53) and number of filled grains/panicle (59.30) were recorded in black gram + aerobic rice with 75% RDN (T_5) and the highest grain yield (1052.07 kg ha^{-1}) and straw yield (3947.25 kg ha^{-1}) were obtained in sole cropping of aerobic rice (T_3). Among the intercropping treatments, the highest rice grain yield (550.48 kg ha^{-1}) was recorded in black gram + aerobic rice with 75% RDN (T_5) and straw yield (1480.22 kg ha^{-1}) in black gram + aerobic rice with 50% RDN (T_6). High gross returns (Rs.180065 ha^{-1}), net returns (Rs.103858 ha^{-1}) and B:C ratio (2.36) was recorded by cowpea + aerobic rice with 50% RDN (T_9).

Keywords : Aerobic rice, Legume inter cropping system, B : C ratio

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INDIA is the second largest producer of rice with a production of 195 million tonnes from an area of 46.4 million hectares (FAO, 2021). Low land rice production system consumes 4000 to 5000 litres of water for producing 1 kilogram of rice grains. The conventional method of rice cultivation not only wastes water but also emits significant amounts of methane gas into the atmosphere. Aerobic rice is a better alternative to conventional flooded rice where specific 'aerobic rice' varieties are cultivated in non-puddled, non-saturated and well drained soils. It combines the drought tolerance of upland rice and the high yield potential of lowland rice (IRRI, 2022). It requires less water (470-650 mm) and emits less methane than the traditional flooded rice (Bouman *et al*., 2002).

Cereal + legume intercropping imparts a greater scope for curtailing adverse impacts of nutrient and moisture stress along with enhanced system productivity and soil health. Aerobic rice favours the cultivation of short duration pulses as intercrops that improves the use of resources (Subramanian *et al*., 2020). Cowpea and black gram proved to be the leading legume components in the rice + legume intercropping system (Morris *et al.,* 1990 and Sridhar *et al*., 2021). Nitrogen (N) is found to be the most important nutrient limiting the growth and development of cereals. When a cereal crop is intercropped with a legume, the cereal component may be benefitted by direct N transfer from the legume through biological N fixation (Giller, 2001). Thus, it is very important to assess the appropriate dose of N for the cereal component in

intercropping system considering the legume effect. Keeping all these points in view, it was proposed to conduct a field experiment with an objective to analyse the productivity of aerobic rice intercropped with legumes (black gram and cowpea) under varying levels of nitrogen.

Material and Methods

The field experiment was conducted at College of Agriculture, Padannakkad, Kerala Agricultural University during *rabi* season from December 2021 to May 2022. The field was located at 12°14' 38.1" N Latitude, 75°6' 25.2" E Longitude and an altitude of about 5 m above mean sea level.

The soil is loamy sand with slightly acidic P^H (6.5), normal electrical conductivity (0.07 dSm^{-1}), high organic carbon content (1.1%), low available nitrogen (100.35 kg ha^{-1}), high available phosphorus (63.84 kg ha^{-1}) and low available potash (66.75 kg ha^{-1}).

The experiment was laid out in Randomized block design with nine treatments and three replications. The treatments are T_1: Sole crop of black gram, T_2: Sole crop of cowpea, T_3: Sole crop of aerobic rice, T_4: Intercrop of black gram + aerobic rice with RDN, T_5: Intercrop of black gram + aerobic rice with 75% RDN, T_6: Intercrop of black gram + aerobic rice with 50% RDN, T_7: Intercrop of cowpea + aerobic rice with RDN, T_8: Intercrop of cowpea + aerobic rice with 75% RDN and T_9: Intercrop of cowpea + aerobic rice with 50% RDN.

The experimental plot size was 6 m x 2.7 m with a net plot size of 13.2 m^2. From each plot, 10 plants each of rice and legume were selected for recording observations periodically.

Details of crops and varieties used for the study are given below.

For laying out intercropping treatments, the component crops were cultivated in such a way that two rows of aerobic rice were followed by one row of pulse (2:1 sown proportion). The spacing followed was 25 cm x 15 cm for all the three crops. There were 16 rows of aerobic rice and 8 rows of pulse in each plot.

At the time of land preparation, lime was applied at the rate of 600 kg ha^{-1} as per the package of practices recommendations of KAU (KAU, 2016) and FYM @ 5 t ha^{-1} for all the three crops. Fertilisers applied for aerobic rice was at the rate of 100:60:40 kg NPK ha^{-1} as per recommendations of IRRI (IRRI, 2022). As per KAU package of practices recommendations, fertilisers applied for black gram and cowpea were at the rate of 20:30:30 and 20:30:10 kg NPK ha^{-1} (KAU, 2016). The fertilizer materials used for the study were urea (46% N), rajphos (18% P_2O_5) and MOP (60% K_2O). Half of N, full of P and K were applied as basal dose and the remaining half N was applied at 20 DAS for pulse crops. For aerobic rice, N was applied as three equal split doses; basal, at tillering stage and at panicle initiation stage. Full P was applied as basal dose. K was applied in two split doses, half as basal dose and remaining half at panicle initiation stage.

Results and Discussion

Growth Attributes

Effect of treatments on plant height, number of leaves/ hill and number of tillers/ hill are presented in Table 1.

The treatments had no significant impact on plant height and number of leaves/ hill at harvest stage. However, the sole crop of aerobic rice (T_3) recorded higher values for both the parameters. These results

Crop	Variety	Released from	Days to maturity	Salient features
Aerobic rice	Sharada (MAS 946 - 1)	UAS, Bangalore	110-115	Drought and blast tolerant, slender grain
Black gram	Sumanjana	KAU, Thrissur	75-80	Suitable for summer rice fallows of Kerala
Cowpea	Pant Lobia-3 (PGCP - 6)	GBPUAT, Pantnagar	65-70	Bush type, resistant to yellow mosaic virus and bacterial blight

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TABLE 1

Effect of treatments on plant height, number of leaves/ hill and number of tillers/ hill of aerobic rice at harvest stage

Treatments	Plant height (cm)	Number of leaves/ hill	Number of tillers/ hill
T_3: sole crop of aerobic rice	85.7	80.47	24.40 [a]
T_4: black gram+aerobic rice with RDN	78.7	54.40	22.13 [a]
T_5: black gram+aerobic rice with 75% RDN	81.9	68.67	21.73 [a]
T_6: black gram+aerobic rice with 50% RDN	82.5	60.00	20.67 [a]
T_7: cowpea + aerobic rice with RDN	78.4	73.53	14.40 [b]
T_8: cowpea+aerobic rice with 75% RDN	72.7	68.27	13.53 [b]
T_9: cowpea+aerobic rice with 50% RDN	78.2	49.20	12.60 [b]
SEm (±)	2.8	10.79	1.58
CD (0.05)	NS	NS	4.87

Note: T_1 (Sole Crop of Black Gram); T_2 (Sole Crop of Cowpea) were used for comparing the effect of treatments on Black Gram and Cowpea respectively when intercropped with Aerobic Rice. Here, for all the Tables, Effect of Treatments on Aerobic Rice was analysed and thus its sole crop and (T_3) Alone was used in the Statistical Analysis

are coincided with Rashwan and Zen El-Dein (2017) who reported no significant effect of N level and intercropping on plant height of cereal. Sannagoudar and Murthy (2018) also reported non-significant effect of plant height and number of leaves of maize in maize+legume intercropping system due to synergistic effect. Sole crop of aerobic rice (T_3) recorded the highest number of tillers/ hill (24.4) at harvest which was on par with black gram + aerobic rice with RDN (T_4), black gram + aerobic rice with 75% RDN (T_5) and black gram + aerobic rice with 50% RDN (T_6). This may be attributed by adequate N availability due to black gram effect and less competition due to low height and low leaf area of black gram for space, nutrients and sunlight to aerobic rice than cowpea. Aerobic rice intercropped with cowpea was dominated in the system as cowpea imparted high competition for resources such as solar radiation, water and nutrients which in turn resulted in vigorous growth of cowpea and less number of tillers in rice. These results were in conformity with Giana (2014) who reported high number of tillers/ hill of pearlmillet in pearlmillet + mungbean than pearlmillet + cowpea intercropping and 75 per cent recommended dose of nitrogen.

TABLE 2

Effect of treatments on chlorophyll content (SPAD Index) and leaf area index (LAI) of aerobic rice at 60 DAS

Treatments	Chlorophyll content (SPAD Index)	LAI
T_3: sole crop of aerobic rice	37.18	6.00
T_4: black gram+aerobic rice with RDN	35.49	4.68
T_5: black gra+aerobic rice with 75% RDN	35.93	4.14
T_6: black gram+aerobic rice with 50% RDN	36.20	3.53
T_7: cowpea + aerobic rice with RDN	35.75	2.83
T_8: cowpea+aerobic rice with 75% RDN	35.44	3.31
T_9: cowpea+aerobic rice with 50% RDN	36.04	3.51
SEm (±)	0.86	0.65
CD (0.05)	NS	NS

Table 2 describes the effect of treatments on leaf area index and chlorophyll content (SPAD index). The treatments had no significant effect on leaf area index and chlorophyll content (SPAD) of aerobic rice at 60 DAS. However, the sole crop of aerobic rice (T_3) recorded higher values for both the parameters. These results were in conformity with Wang *et al.* (2014) who reported no significant difference of plant height and SPAD index of maize in maize + soybean intercropping under varying level of nitrogen.

Yield and Yield Attributes

Effect of treatments on yield, yield attributes and harvest index of aerobic rice are presented in Tables 3 and 4. As presented in Table 3, the highest number of productive tillers/ hill (21.27) was recorded by black gram + aerobic rice with RDN (T_4) and it was at par with sole crop of aerobic rice (T_3), black gram + aerobic rice with 50% RDN (T_6) and black gram + aerobic rice with 75% RDN (T_5). Due to incorporation of black gram, there may be high N availability by biological N fixation and less competition for resource like light and space than cowpea.

The highest number of spikelets/panicle (77.53) was found in black gram + aerobic rice with 75% RDN (T_5) and it was at par with sole crop of aerobic rice (T_3), black gram + aerobic rice with RDN (T_4), black gram + aerobic rice with 50% RDN (T_6) and cowpea + aerobic rice with RDN (T_7) as described in Table 3. The highest number of filled grains/ panicle (59.30) was recorded in black gram + aerobic rice with 75% RDN (T_5) which was on par with black gram + aerobic rice with 50% RDN (T_6), sole crop of aerobic rice (T_3) and black gram + aerobic rice with RDN (T_4) as given in Table 3. Similar findings were reported by Naik *et al*. (2017) and Roshini *et al*. (2022) who reported high number of spikelets/ panicle at RDN which was at par with 75% RDN.

The grain yield, straw yield and harvest index are presented in Table 4. The highest grain yield (1052.07 kg ha^{-1}) was recorded by sole crop of aerobic rice (T_3). Among the intercropping treatments the highest grain yield (550.48 kg ha^{-1}) was recorded in black gram + aerobic rice with 75% RDN (T_5) which was on par with black gram + aerobic rice with 50% RDN (T_6), black gram + aerobic rice with RDN (T_4) and cowpea + aerobic rice with RDN (T_7). This could be attributed by high plant population and better yield attributes of aerobic rice in sole cropping than intercropping. These results are in conformity with Ghosh *et al*. (2009), Chu *et al*. (2004) and Ram and Meena (2014) who reported high grain yield in sole crop of cereal in cereal + legume intercropping. Aerobic rice yield was severely affected by rice bug (*Leptocorisa oratorius*) infestation, for which control measures were taken by spraying and dusting malathion. Eventhen, the

TABLE 3

Effect of treatments on number of productive tillers/ hill, number of spikelets/ panicle and number of filled grains/ panicle of aerobic rice

Treatments	Productive tillers/ hill	Spikelets/ panicle	Filled grains/ panicle
T_3: sole crop of aerobic rice	20.33 ^{a}	77.30 ^{ab}	53.70 ^{a}
T_4: black gram+aerobic rice with RDN	21.27 ^{a}	73.03 ^{ab}	50.13 ^{a}
T_5: black gram+aerobic rice with 75% RDN	19.27 ^{a}	77.53 ^{a}	59.30 ^{a}
T_6: black gram+aerobic rice with 50% RDN	19.67 ^{a}	70.83 ^{ab}	54.43 ^{a}
T_7: cowpea + aerobic rice with RDN	12.93 ^{b}	61.83 ^{abc}	20.20 ^{b}
T_8: cowpea+aerobic rice with 75% RDN	12.73 ^{b}	60.37 ^{bc}	19.17 ^{b}
T_9: cowpea+aerobic rice with 50% RDN	11.20 ^{b}	51.20 ^{c}	20.03 ^{b}
SEm (±)	1.631	5.53	6.63
CD (0.05)	5.025	17.03	20.43

TABLE 4

Effect of treatments on grain yield, straw yield and harvest index of aerobic rice

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
T_3: sole crop of aerobic rice	1052.07 ^{a}	3947.25 ^{a}	0.20
T_4: black gram+aerobic rice with RDN	424.97 ^{bcd}	1166.44 ^{bc}	0.27
T_5: black gra+aerobic rice with 75% RDN	550.48 ^{b}	1271.03 ^{bc}	0.31
T_6: black gram+aerobic rice with 50% RDN	529.56 ^{bc}	1480.22 ^{b}	0.26
T_7: cowpea + aerobic rice with RDN	237.61 ^{bcd}	754.89 ^{c}	0.27
T_8: cowpea+aerobic rice with 75% RDN	118.69 ^{cd}	750.34 ^{c}	0.24
T_9: cowpea+aerobic rice with 50% RDN	38.65 ^{d}	734.43 ^{c}	0.05
SEm (±)	139.97	206.37	0.06
CD (0.05)	431.30	635.89	NS

damage was remarkable and a score of 7 (IRRI, 2002) was given to damaged grains for all treatments.

The highest straw yield of aerobic rice (3947.25 kg ha^{-1}) was recorded by sole crop of aerobic rice (T_3). Among the different treatments of intercropped systems, the highest straw yield was recorded in black gram +aerobic rice with 50% RDN (T_6) which was on par with black gram + aerobic rice with 75% RDN (T_5) and black gram + aerobic rice with 75% RDN (T_4). The reason may be due to high plant population in sole crop of aerobic rice and efficient utilisation of available resources without any competition, which ultimately leads to a greater yield and high growth parameters leads to high dry matter accumulation in sole crop of aerobic rice. These results agree with Sridhar & Salakinkop (2021) and Srinivasan (2002) who reported higher straw yield from sole crop of cereal than intercropped cereal. The treatments had no significant effect on the harvest index. However, black gram + aerobic rice with 75% RDN (T_5) recorded the highest harvest index (0.31).

Economic Analysis

The economics of cultivation is presented in Table 5. The highest gross returns (Rs.180065 ha^{-1}), net returns (Rs.103858 ha^{-1}) and BCR (2.36) was recorded by cowpea + aerobic rice with 50% RDN (T_9). This is imparted by very high pulse yield of cowpea compared to black gram. These results are coincided with Singh and Srivastava (2018) as well as Srinivasa Reddy *et al.* (2023) who reported high net returns and B:C ratio in cereal + legume intercropping than cereal sole cropping.

Effect of N on growth parameters, yield attributes, yield and economics of cultivation of aerobic rice intercropped with cowpea/ black gram reveals that aerobic rice + legume intercropping system can reduce

TABLE 5

Effect of treatments on economics of cultivation

Treatments	Cost ofcultivation (Rs.ha^{-1})	Grossreturns (Rs.ha^{-1})	Net returns (Rs.ha^{-1})	BCR
T_3: sole crop of aerobic rice	71894	29984	-41910	0.42
T_4: black gram+aerobic rice with RDN	73588	56165	-17423	0.76
T_5: black gra+aerobic rice with 75% RDN	73364	74207	843	1.01
T_6: black gram+aerobic rice with 50% RDN	73136	81471	8335	1.11
T_7: cowpea + aerobic rice with RDN	76659	176494	99835	2.30
T_8: cowpea+aerobic rice with 75% RDN	76435	169957	93522	2.22
T_9: cowpea+aerobic rice with 50% RDN	76207	180065	103858	2.36

the N fertilizer requirement. Regarding growth and yield attributes of aerobic rice, intercropping with black gram was found better; but high gross returns, net returns and benefit cost ratio were recorded by cowpea intercropping treatments. Intercropping with legume is better than sole cropping of aerobic rice in terms of economic returns.

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